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Cloud-based COVID-19 Patient Monitoring using Arduino

1st Ibrahim Kareem Hanoon
Department of Information and Communications Engineering
College of Information Engineering
Al-Nahrain University
Baghdad, Iraq
ibrahim.kareem@coie-nahrain.edu.iq

2nd Mohammed I. Aal-Nouman
Department of Information and Communications Engineering
College of Information Engineering
Al-Nahrain University
Baghdad, Iraq
m.aalnouman@coie-nahrain.edu.iq

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***Abstract*—IoT is considered as one of the fastest growing technology in the medical and industrial fields, and one of its use is the transmission of the Medical information of the patients to the general practice (GP) or hospitals. And because of the last situation of the COVID-19, and the increasing number of the infected people, the researchers started to focus on how to transmit and monitor the patients' information remotely in order to decrease the chance of infection. This paper introduces an affordable IoT-based application aiming to decreases the chance of COVID-19 infection transmission. The proposed device can help the patients by checking their health status, while doctors remotely monitor this information. This paper presents a measuring and recording device for heart rate, oxygen saturation levels, and body temperature. An Arduino device with sensors will be used to measure these records and send them to the cloud server. The results show that the information has been sent successfully to the cloud.**

Keywords—ATmega, ESP8266, pulse rate, spo2, temperature, covid-19, internet of things

I. Introduction

Internet of Things (IoT) opens new opportunities to the researcher to collect and transmission data to the servers in order to improve those system and make a fast decision [1]–[4]. IoT applications can help many in many fields, including but not limited to smart cities, industry and healthcare [5]–[9]. Right now, the most utilization of IoT in healthcare can be summarized as remote monitoring of the patients status in real-time [1]. IoT networks could be used to control and manage situations, like in 2020, when coronavirus disease (COVID-19) hit the world, without putting extreme constraints on individuals and businesses [2], [3]. COVID-19 causes respiratory disease and has been more contagious compared to SARS in 2003 [2]. The recommended official procedure to control viruses' spread is to observe physical (or social) distancing until vaccines are available. Contagious infections would have a lower risk of spreading if improved monitoring programs, healthcare, and transportation are implemented [10]–[13]. A standard IoT device for healthcare is made up of various sensors connecting to a microcontroller and/or a server, which provides a real-time reading of the environment or users [3], [6], [10].

In the current pandemic, sensors connected to an AI-algorithm could be helpful to diagnose whether people are infected with the COVID-19 virus based on measurements such as body temperature, blood oxygen levels and coughing patterns. A wireless heart rate and body temperature recording device that provides accurate measurement throughout the day would provide a better and a true picture of patients' health [11]–[13]. The device could also be a research tool to understand better the effects of pulse rate and temperature on overall health. This paper discusses collecting the heart rate and body temperature data. The gathered data can then be sent to a server or a cloud using a wireless connection. These connections include but not limited to Bluetooth, Wi-Fi, 4G, 3G, and GPRS [3], [6], [13]–[17]. The collected data could be sent to cloud storage to perform permanent storage or monitoring in real-time [13]. A mobile applications can be used to observe the patient's information easily [14], [15]. This system is expected to monitor patients' Pulse Rate and Temperature, while doctors monitor the patient's condition remotely without being physically present near the patient's bed [3], [4], [14]. The doctors will produce more accurate results for diagnosing a patient's medical problem, which resulted from observing abnormal Pulse Rate and Temperature readings [4], [5].

Such information will help the authorities to classifiy the patients depends on their risk status, and this will help to give priority to the users dependently [6].

The paper's main objective is to help organizations adhere to the safety protocol and guidelines related to COVID-19 to help stop the virus spreading. The real-time health monitoring of patients by connecting multiple sensors to Arduino that collects data and transmits it to a cloud server could help save both patients' and doctors' lives.

The paper is organized as follows; section II presents similar works Section III presents the proposed system architecture showing the hardware and components used, cloud subsystem, and database. Section IV shows system implementation, section V shows some results and findings. Finally, the conclusion is shown in section VI.

II. Similar Works

Several IoT healthcare and assisted living applications and systems are shown in this section. Like, In [4], where a MAX30100 sensor that attached to ESP32 microprocessor in order to collect patient's heart rate and Spo2, and the results are sent to a server using the MQTT protocol and Wi-Fi technology. In [3], a similar system utilizing using NodeMCU and smartphones for remote temperature control.

A remote smart grid monitoring anomaly, power consumption monitoring, and relay protection using IoT devices is presented by [1] using nodeMCU. This researcher used a nodes developed on the Raspberry Pi Zero (RPIZ) for the COVID-SAFE platform, they divided the system into three parts: a wearable IoT system, mobile app, and a fog (or cloud) server. The IoT node connects to the user's smartphone using Bluetooth to gather proximity data and communicate with the server over the cellular data network. This paper proposed an IoT application for a basic patient health tracking system. The computer keeps track of the heart rate and body temperature and sends the information to a web server.

ThingSpeak is the IoT server which used in [2], also the GPS sensors and ECG sensors were connected to a patient to collect locations, temperature, heartbeat, and symptoms indicating the COVID-19 disease. The data is later saved in a local database, and doctors are informed after sending data to the main server.

III. Proposed System Architecture

This paper will propose a system that do patients check their health status, while doctors remotely monitor their patients' health status to achieve that goal, the designed system (as shown in Fig. 1) consists of sensors to measure the heart rate and blood oxygen level (MAX30100) and body temperature (MLX90164), which connects to a microprocessor (ATmega 2560) by using the synchronous serial communication protocol inter-integrated circuit (I2C) is one of the communication protocols used in embedded systems [4]. ATmega 2560 access the internet via ESP8266-01 using Wi-Fi technology using TCP protocol [5], [18]. The system has been designed to monitor the patients' health status periodically through a network of connected sensors. The sensors are used for gathering biological measurements of a patient. This system is designed to address the Covid-19 patients. The collected biological measurements are then forwarded to an IoT cloud. The system can detect life-threatening conditions by processing sensors' data and promptly notify doctors, nurses, and hospital personal [6], [11], [16]. The health care providers get benefits from this system because it allows observing patients remotely without being physically in contact. Patients' relatives can also obtain limited access to this notification after the patient consent. The system will have two main subsystems: first is the hardware components, second is the database that is in the Cloud.

A. Hardware Components

This sub section briefly presents the hardware components used to build the system and discuss the web technologies used to develop the cloud side.

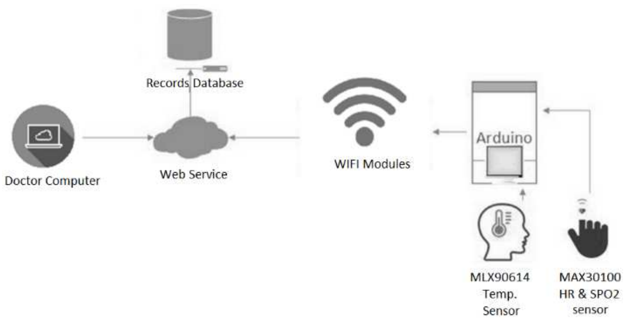

Fig. 1. System overview

TABLE I. Hardware List

List	Purpose
Arduino Mega 2560	Main controller
MAX30100 Sensor	Measure SPO2 and Heartrate
MLX90614 Sensor	Measure Temperature
OLED Display	Display result

Fig. 2. Database Overview

Fig. 3. Table Overview

B. Cloud Subsystem

Usually the IoT needs the Cloud in order to save the users information to be retreaved later or instant [18], [19]. In this subsystem, a database is used in order to collect the relevant data from the query string and provide fast access to data being handled by the system. These data structures contain indexes to speed up access to the data. The software used to design this database is phpMyAdmin. phpMyAdmin is written in PHP and envisioned to manage MySQL administration over the internet. It supports an extensive range of processes on MySQL and MariaDB. Some of the most frequently used processes are databases, tables, columns, relations, indices, users, permissions, and so on are all managed. It can be done via the user interface, but users can also run every SQL statement directly [19].

C. Database Relationship

Three tables were created for patients, each table for one patient, as shown in Fig. 2. Each table content six columns (id, temp, heart rate, spo2, date and time), id is primary key and auto-increment, date and time are used current_timestamp() function that explains what real-time that data received in the database as shown in Fig. 3.

IV. System Implementation

A. Designing the Microcontroller, sensors, and Programming steps

The prototype of the IoT system is presented in Fig. 4. When the circuit is turned on, the Arduino begins reading the pulse sensor's pulse rate as well as the ambient temperature of the MLX90614 temperature sensor. An infrared LED and a phototransistor in the heart rate monitor help tracking the pulse at the fingertip or earlobe. When it senses a pulse, the IR LED pulses. When it senses a pulse, the IR LED pulses. The phototransistor detects the infrared LD flashes and adjusts its resistance as the pulses change. The normal adult's heart rate is 60 to 100 beats per minute. An interrupt is first set to occur every two milliseconds in order to detect beats per minute (BPM). Fig 4. Shows the system setup.

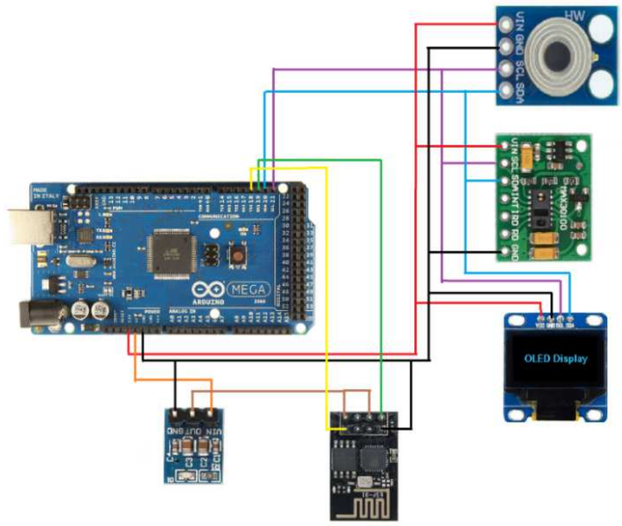

Fig. 4. Experimental Setup for the Device

MLX90614 is a high accuracy contactless temperature sensor. It can be used to collect body temperature measurement when the distance between body and sensor is between 2cm and 5cm. The sensor communicates with the microcontroller using the I2C protocol. Both sensors (MAX30100 and MLX90614) that will sense depend on beat detected after finger placed on MLX30100 for 10 times and will go this sensor to shutdown mode, the last reading saved then transmitted serially to the Wi-Fi module via serial communication protocol inter-integrated circuit (I2C).

Fig. 5 shows the flow diagram of the proposed system. Patients should place a finger on the sensor probe. There is a source on the probe that emits light and a receiver works as a light detector (photodiode).

The procedure of programing went through two sub procedure as programming of the ESP8266 and programming of the MEGA 2560 as follows:

1) Programming steps for the ESP8266 module: The Wi-Fi module connects to SSID network that comment used as shown below.

- AT+CWJAP= "ssid name", "password"

After a connection is established, send data through a TCP connection

- if a connection exists and send success

  – SEND OK
- if send fail

  – SEND FAIL
- if TCP disconnect

  – CONNECTION CLOSE

2) Programming steps for the MEGA 2560: When get SEND OK as shown in Fig. 6, The data will be coming from Mega 2560 and routed to the ESP8266 module first and then transmitted by internet to web server, in order to be stored in tables of the database in the cloud.

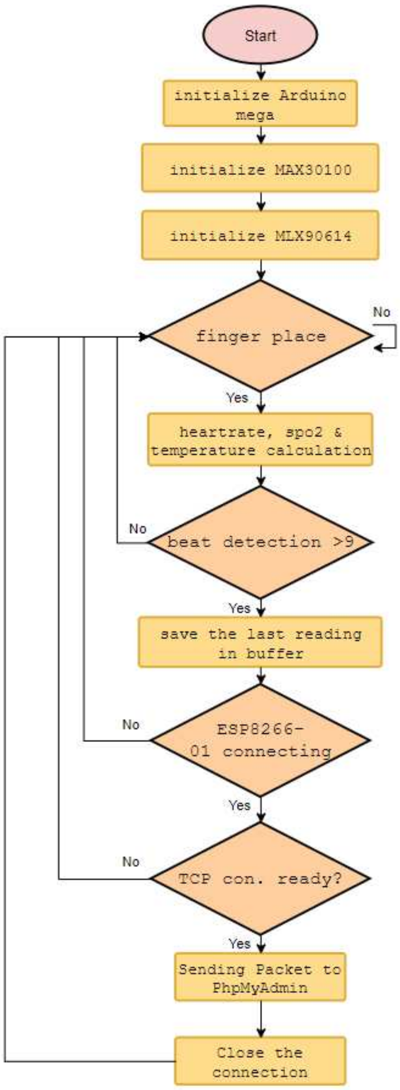

Fig. 5. The Flow Diagram of the Proposed System

```
COM3

Heart rate:79bpm / SpO2:96%/Temperture:32C
Module Reset
AT+CWJAP="ibrahimh","12345678ib"

OK, Connected to WiFi.
TCP connection ready
Sending..
Packet sent

Recv 206 bytes

SEND OK

+IPD,361:HTTP/1.1 200 OK
Date: Mon, 25 Jan 2021 23:42:40 GMT
Content-Type: application/json; charset=UTF-8
Content-Length: 54
Connection: keep-alive
Access-Control-Allow-Origin: *
Server: awex
X-Xss-Protection: 1; mode=block
XCntent-Type-Options: nosniff
X-Request-ID: e7021cb5e5eedabf11fe5476907e8a19

{"success":1,"message":"upload successfully created."}

Autoscroll  Show timestamp                    Both NL & CR
```

Fig. 6. View Program Upload Results

The procedure can be summarised into two stages, first stage started when the microcontrol initiated, the sensors initialized and read the values from the patient and display the results of these sensors on the OLED attached to the hardware that attached to the user. Then the values will be prepared in order to be sent via the Wi-Fi in the second stage as shown in Fig. 7

The second stage process the values that gotten from the sensors converting them into strings, initiated the Wi-Fi, check the connection status like the SSID and password and then send the data to the cloud as shown in Fig. 8.

B. Implementation of Webserver and Webpage

The web server is one of the utmost important component of the system. It is in control for handling the request made by the Microcontroller and sensing unit. The web server is hosted under www.000webhost.com cloud hosting. The web server is configured with PHP and mainly deals with json file and txt file. The PHP script contains some code that does some basic processing and storing the data collected by PHP $_POST superglobal variables contained within the PHP script. The PHP script is implemented for each appliance and sensors. The web server collects the relevant data from the query string added with the URL. The webpage is built using HTML, CSS, and JavaScript. HTML is used to describe a web page's text, CSS is used to determine the structure of a web page, and JavaScript is used to program the actions of a web page. The webpage can be accessed through http://covid19a.000webhostapp.com/apl as shown in Fig. 9.

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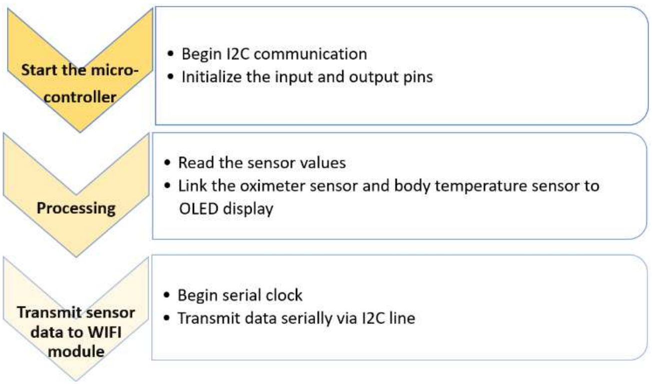

Fig. 7. Microcontroller First Procedure

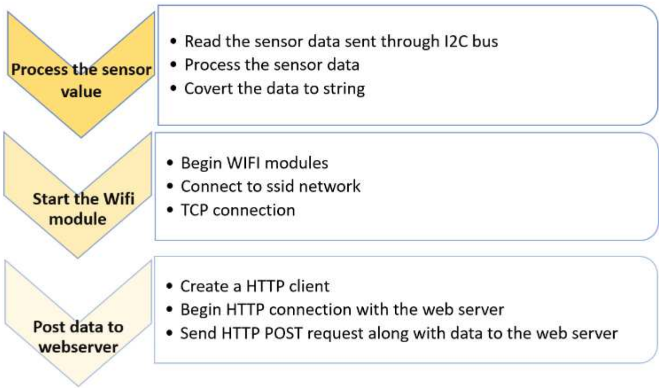

Fig. 8. Wi-Fi Procedure

(COVID-19) Situation Report for (p101)

#id	temperature	heart rate	SPO2	Date	Time
1	34 C	76 bpm	95 %	2021-01-19	03:14:48
2	35 C	75 bpm	95 %	2021-01-19	03:15:10
3	34 C	63 bpm	96 %	2021-01-19	03:15:35
4	36 C	69 bpm	95 %	2021-01-19	03:15:59
5	33 C	76 bpm	95 %	2021-01-19	03:16:24
6	34 C	75 bpm	95 %	2021-01-19	03:17:06
7	36 C	71 bpm	95 %	2021-01-19	03:17:27
8	35 C	84 bpm	95 %	2021-01-19	03:17:49

Fig. 9. Webpage Running under 000webhost.com

V. RESULTS

This portion contains some of the findings of evaluating the MAX30100 sensor's precision in measuring blood oxygen saturation and heart rate. The results are compared with Oximeter as the Industry-standard measuring device. The section also presents the results of testing the accuracy of the MLX90614 sensor that measures body temperature against digital thermometer as the Industry-standard.

Table 2 presents the results of humans' body temperature measurement accuracy using the MLX90614 sensor. The measurements were carried out three times in three different patients. The collected test results are then compared to a digital thermometer.

Table 3 presents the Oxygen Saturation detection sensor's accuracy, while Table 3 presents the Heart Rate results. The tests were carried out as many as three tests in three different patients. Test results are then compared with Finger Oximeter (FO) as the industry-standard measuring device. The made system's reliability efficiency is also very stable, as demonstrated by the slight standard deviation rating.

TABLE II. TESTS ACCURACY OF BODY TEMPERATURE

Name	Age	MLX90614	Temp.	Accuracy
Tariq	35	35 C	35.02 C	99.94 %
Hamza	55	33.92 C	34 C	99.76 %
Yousif	22	36.45 C	36.5 C	99.86 %
Ahmed	29	35.5 C	35.8 C	99.16 %
Noor	48	36.2 C	36.5 C	99.17 %

TABLE III. TESTS ACCURACY OF OXYGEN SATURATION IN BLOOD

Name	Age	MAX30100 SPo2	FO	Accuracy
Tariq	35	95 %	96.5 %	98.44 %
Hamza	55	94.1 %	97 %	97.01 %
Yousif	22	93.8 %	96 %	97.77 %
Ahmed	29	97 %	98 %	98.97 %
Noor	48	96.5 %	98 %	98.46 %

TABLE IV. TESTS ACCURACY OF THE HEART RATE

Name	Age	MAX30100 heart rate	FO	Accuracy
Tariq	35	68.5 bbm	70.2 bbm	97.57 %
Hamza	55	84.7 bbm	81 bbm	95.63 %
Yousif	22	74.6 bbm	78.2 bbm	95.39 %
Ahmed	29	62.3 bbm	66.5 bbm	93.68 %
Noor	48	88.5 bbm	85 bbm	96.04 %

VI. CONCLUSION

An intelligent system for monitoring and recording patients' health information through a network of connected sensors was designed and tested. This system is specially developed to address the needs of the COVID-19 patients. Sensors aretable used for collecting the vital health measurement of the patient. The collected information is then uploaded to an IoT cloud. The system can detect the life-threatening condition of a patient by processing sensors' data and promptly alert doctors/nurses and hospital personal. The health care providers benefit from this system because it allows observing patients remotely without being physically in contact with the patient. Patients' family can also obtain limited access to this notification after the patient consent. The resuls show how this information has been sent successfully and stored in the cloud.

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